Linnaeus: King of Natural History

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Linnaeus' legacy was far more encompassing than taxonomic. We argue that, while the systematic recording of species remains fundamental to modern ecological concerns, Linnaeus also laid the foundation for other major areas of ecology, including comparative biogeography, plant demography, and comparative anatomy.

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INTRODUCTION

Linnaeus is one of the towering figures in the history of biological science. He is remembered today chiefly for his introduction of the binomial system of nomenclature and for his taxonomy. However, if we consider his skill as an observer of the relationships between the plants and animals he classified, and their environment, he should also be regarded as one of the earliest practicing ecologists. He passed on these skills to his many students, including those who travelled the world collecting and classifying organisms and became known as the 'apostles'.

In eighteenth-century Sweden, Linnaeus was accorded high status, and this great respect continued to hold internationally until the twentieth century. Lord Rutherford's throw-away comment that '(a)ll science is either physics or stamp collecting' reflected the marginalization of taxonomy and natural history within science as technological advances in physics, chemistry and engineering attracted funding and support. These advances also revolutionised biology, permitting breakthroughs in physiology, biochemistry and the molecular sciences, but in this brave new world the diversity and distribution of organisms lost their attraction as fields of study. It was only towards the end of the twentieth century when environmental issues became such a major theme in politics and with the public that there was renewed interest in the study of biodiversity, and a need to bring new techniques and approaches to 'old fields'. By then, many of the essential skills underpinning the study of biodiversity were already in decline. (Biodiversity itself is a word of recent origin – first coming to the fore with the publication of Wilson [1988].)

The taxonomic side of Linnaeus' achievements was outstanding. While his sexual system did not long survive as a basis for plant classification, Linneaus had grasped the potential for classification to be predictive and 'natural', even if his particular approach had its limitations. He had recognized the importance of the hierarchical approach and provided a nomenclatural system that was functional and, importantly, had practical application to the large number of new species that were being discovered outside Europe. It was the first classification system that was accessible to the non-specialist, with the work encapsulated in handbooks that were 'small enough to be carried into the field' (Koerner, 1999, p40).

In the year 2007, we celebrated the tercentenary of Linnaeus' birth. It also happens to be the anniversary of Georges-Louis Leclerc, Comte de Buffon, the author of the *Histoire Naturelle*. Conniff (2007), in his article aptly titled *Happy Birthday, Linnaeus*, argues that Buffon should be regarded as at least the equal of Linnaeus, and in particular suggests that Buffon had a superior understanding of habitat, anticipating the development of ecology as a science. Linnaeus and Buffon were mutually fierce critics, and Buffon was undoubtedly also a major figure in the history of science: he had better geological insight than Linnaeus, and was closer to having an evolutionary perspective. However, to suggest that Linnaeus' natural history was not ecologically focused is far from accurate. A major part of Linnaeus' teaching was based on field excursions: he had a very comprehensive knowledge of the local flora of southern Sweden, and while his sexual system was not appropriate for higher taxonomic ranks, Linneaus' species concepts have largely stood the test of time.

We would argue that Linnaeus' taxonomic work was firmly underpinned by a deep understanding of natural history and that natural history in turn provided the basis for ecology (Mayr, 1997; Blunt, 1971). The ecological insights of Linnaeus are clearly seen in his botanical 'text book', *Philosophia Botanica* (Linnaeus, 1751). Koerner (1999) notes that '…he described many of the mechanisms of species interdependence, as Charles Darwin noted on reading his *Oeconomia naturae* of 1749' (p15).

LINNAEUS AND NATURAL HISTORY

'Natural history', the advancement of which is the prime objective of the various Linnean Societies around the world, has a very long history. Early hunter-gatherer societies could not have survived unless members possessed what we might consider to be an innate understanding of natural history, including the ability to recognise different sorts of food and to distinguish between the edible, the toxic and the dangerous. Cave paintings provide, in a tangible form, evidence for knowledge of natural history. In classical times, plants and animals were seen as sources of medicines or as an element in a broader natural philosophy, and the Greeks and Romans left a documentary record which at least in part survives to this day and that would have been known to Linnaeus. Knowledge of natural history would have been current amongst the broader population, the majority of which lived in rural environments and were intimately dependent on the natural world for survival, but in 'academic' circles natural history was increasingly associated with medicine. For hundreds of years herbalists recycled the writings of classical authors, without making original observations and with the claims becoming more fanciful on each retelling. The Renaissance then brought a new curiosity about the world and more organized scientific inquiry, although the importance of the links to medicine continued, and old myths still retained currency. Linnaeus himself was Professor of Medicine and Botany at Uppsala University, and in some institutions close links between the two disciplines survived until the twentieth century. The recent growth of interest in alternative medicine suggests a need for revitalizing the links to scientific botany, and ethnobotany has been given a new impetus as a field of study by the regime for rewarding traditional owners of knowledge and resources, which was established by the United Nations Convention on Biological Diversity 1992.

From the late 16th century onwards there was a considerable interest in collecting and studying 'curiosities' of all kinds, and some of the collections of natural history objects that were assembled were large. Some of the more academic natural historians associated with these collections were distinguished scientists whose work has stood the test of time. An example is John Ray, who was the first to draw a distinction between Monocots and Dicots and who is commemorated in the still existing Ray Society and in the name of the herbarium at the University of Sydney. Some of the impetus for collecting was stimulated by the increasing numbers of exotic specimens being sent back to Europe from wider exploration. Linnaeus was very much part of this natural history tradition and although he did not travel beyond Europe, he actively encouraged his students to do so, and he was familiar with non-European plants both in the form of herbarium specimens and in gardens. The non-European species he described famously included bananas, which would then have been regarded as very exotic.

Linnaeus' own exploration was closer to home and included his early expedition to Lapland. Although there are suggestions that his account of his travels is somewhat exaggerated[1] (Koerner, 1999), it established his reputation as an explorer and natural historian. Lapland in the eighteenth century was at the edge of the world and for many Europeans would have been regarded with as much trepidation as Africa. Even today it remains one of the few wilderness areas in Europe (Ratcliffe 2006).

Once he was established as a senior academic in Uppsala, field teaching became an essential and popular part of Linneaus' teaching. His excursions attracted large numbers of students and were organized with almost military precision (Blunt 1971). Most attention was paid to the flora, although any matter of natural history interest was open for study and comment. Many of the localities around Uppsala that were visited on excursions still support the same species today, so that it requires no great stretch of the imagination to visit sites today and see what Linneaus' students would have seen, and to experience the same excitement of first encountering a wet meadow full of snakeshead fritillaries (*Fritillaria meleagris*) or a dry calcareous esker with a spring abundance of Pasque flowers (*Anemone pulsatilla*).

LINNAEUS AND ECOLOGY

William Stearn (in Appendix I of Blunt, 1971) recognised that Linnaeus has been variously declared 'a pioneer ecologist, a pioneer plant-geographer, a pioneer dendrochronologist, a pioneer evolutionist…' but considered that the 'most influential and useful of his contributions to biology undoubtedly is his successful introduction of consistent binomial specific nomenclature'.

It is true that Linneaus' contribution to ecology and plant geography is rarely acknowledged within these disciplines, and the recognized founding fathers were all much more recent. Nevertheless his *Philosophia Botanica* contains many ecological insights, which were in the published literature and were dormant seeds for many decades. Given the very large number of students who attended Linneaus' classes, and the wide circulation of his publications, the ecological perspective he developed must have been assimilated into the perceived wisdom of the day, and when ecology and plant geography developed as separate disciplines, Linneaus' ideas would have been part of the assumed background.

Today the major concerns of ecology include the identification and evaluation of biodiversity. Of the three generally accepted levels of biodiversity, Linneaus was ignorant of genes, but he clearly recognized the need to document species, and recognized that species occupied habitats. In fact, he devotes part of the *Philosophia* to discussing the main habitats (communities) in Sweden. He also indicated what notes should be made on field excursions.

Unfortunately, the details on many herbarium labels in current collections fail to provide any ecological information. Linnaeus' advocacy of the systematic recording of habitat data was part of his approach to cataloguing information and these features are easily accommodated in modern databases. If Linnaeus were alive today, he would undoubtedly be active in the development of bioinformatics and the creation and manipulation of databases. The omissions of the past cannot be corrected but today's collectors should be encouraged to record much more than is often the case. Regrettably, ecologists are often amongst the worst offenders when it comes to a lack of detail associated with voucher specimens.

Linneaus was well aware of the variability displayed by some species and devoted Chapter IX of the *Philosophia* to a discussion of 'Varieties'. He urged against giving taxonomic recognition to environmentally determined phenotypic variation, as he recognized that a variety of diseases and insect attack could cause abnormalities in plants (*Philosophia* section 312), displaying evidence of very careful observation. He also pointed out that variation could be correlated with soil conditions and microclimate and advocated an experimental approach (*Philosophia* section 316: 'Cultivation is the mother of very many varieties and is the best means of testing varieties'), foreshadowing by a century and a half experimental taxonomy (genecology), which enjoyed its heyday in the second half of the 20th century.

Chapter XI of *Philosophia* (entitled 'Sketches') contains much ecological material. Section 334 'The native locations of plants relate to *region, climate, soil* and *ground*' contains a very succinct introduction to ecology and biogeography (as well as some rather strange views about geology). The discussion about the relationship between latitude and flora gives hints of the ideas subsequently developed in greater detail by Alexander von Humboldt. The relationships between soil types and the plants they support also introduce topics that formed a major part of ecological research in the twentieth century. Section 335 provides an overview of phenology and indicates that Linnaeus was well aware that factors such as temperature and day length were involved in controlling flowering, although it was to be many years before physiological understanding of the mechanisms involved was achieved. Even on botanical excursions students recorded the plant species eaten by particular animal species 'while watching the botanical specimens disappear at the moment they realized that they needed to identify them' (Koerner 1999 p49).

Chapter V of *Philosophia* (Sex) includes observations on annual seed production of individual plants, probably the first scientific exploration of plant demography. The essential feature of the *Philosophia* is the importance of observation, and it is remarkable how much was achieved using lenses and microscopes that today would be regarded as woefully inadequate.

While Linnaeus was a creationist, the recognition of variation suggests that he was not as rigidly so as he is usually portrayed - he certainly recognized that the appearance of species could change. A synthesis of Buffon's and Linnaeus' ideas could have accelerated the development of evolutionary theories, well ahead of the publications of Darwin and Wallace in the mid 19th century.

The *Philosophia* is also strongly focused on the utilisation of plants, not just as medicines but for a whole range of purposes. The 365th (and final) article states: 'The economic use of plants is of great utility to the human race.' (Linnaeus, 1751). One of the major justifications for biodiversity conservation is the maintenance of the ecosystem services that biodiversity supports. This is a concept that would clearly have found favour with Linneaus, and the sorts of observations he advocated are needed to document ecosystem processes. He recorded details of the trophic interactions between organisms and had an appreciation of the recycling of materials, noting people used churchyard soil for growing cabbages, hence 'human heads ... turn into cabbage heads' (Koerner, 1999, p83).

Robert MacArthur (1972) famously wrote that 'to do science is to search for repeated patterns' and stressed the importance of natural history as the starting point for ecological research. MacArthur pointed out that not every natural historian was a scientist (in terms of approach and method, not necessarily profession) and not all ecologists were natural historians, but we would agree with him that most of ecology has its roots in natural history: even theoretical mathematical ecology starts with ideas that are ultimately based on field observation. Underwood (2007) has recently observed 'one of the great joys of experimental ecology is that natural history is so important in the development of explanatory models'.

COLLECTING BIODIVERSITY: PRESERVING BIODIVERSITY?

In the eighteenth, nineteenth and early twentieth century much natural history involved collections; and many large collections of, for example, insects, bird eggs, or plants were made both by, or for, major institutions and individual collectors. Many people who subsequently became famous scientists in other fields (for example Macfarlane Burnet - Sexton 1999) were avid collectors in their youth. Charles Darwin himself was an avid beetle collector in his college days (preferring 'beetling' to mathematics - Desmond and Moore 1991). (Another suggestion for Linnaeus' mis-representation of his travels in Lappland was mis-calculation (Selander, 1947 in Koerner, 1999). Perhaps he shared Darwin's aversion to mathematics?). The making of collections taught the need for careful observation, systematic recording of data, and provided in-depth understanding of particular groups of organisms.

Collectors and recorders were not just the clergy and the landed gentry (or their spinster siblings); there was, at least in the United Kingdom, a very strong working class element of miners and factory workers, who, in their very limited free time, spent many hours completing arduous hikes and making major finds of often taxonomically-challenging organisms. This tradition of the extremely skilled amateur was never as strong in New South Wales as it was in the United Kingdom (for reasons that perhaps require the attention of a social historian). Certainly, there have been some very gifted amateurs, but their interests tended to be restricted to groups such as birds or flowering plants; there was not the same interest or expertise shown in, for example, cryptogamic plants as was the case in the United Kingdom. Given the dearth of professionals in Australia, this means that there are major components of biodiversity about which we remain still basically ignorant.

Today collection is frowned upon, and in many cases (such as the collecting of bird eggs) it is properly illegal. The shift away from collection partly reflects lack of opportunity given an increasingly urbanized population, rejection of a 'stamp collecting' approach to science and greater concern for conservation. Certainly, it would not be possible to condone egg-collecting or capturing and killing native vertebrates outside specially-approved scientific licences, but nevertheless it is probable that both school and university students are missing out on what previously had been important educational experiences.

The old collections remain of continuing value, providing comparative material for taxonomic studies, as well as evidence of changing distributions or of environmental change. For example, the ability to measure long-term trends in thickness of the shells of raptor eggs was extremely important in drawing attention to the effects of the new post-war organic agricultural chemicals (Ratcliffe 1967, 1970; Olsen and Olsen 1979). Sadly, curation of historical collections in some of our greatest museums is being eroded as funding for the care of collections, in the management schemes of modern-day directors, is coming a distant second behind promotion of exhibitions for entertainment's sake without the underlying scholarship being obvious.

Even in the absence of collections, skilled amateurs in the United Kingdom have been able to systematically record distributions of large numbers of taxa at the national scale. These spatially explicit data are of enormous value for monitoring environmental change. Data of this sort would be very difficult to collect (and inordinately expensive) if we had to rely on professionals, yet they will be crucial to our monitoring of biodiversity. In Australia the ornithologists have pioneered systematic recording of species distribution at the continental scale, harnessing the skills and enthusiasm of amateurs and professionals. The differences in distribution and abundance between the two editions of the Bird Atlas (Blakers et al. 1984; Barrett et al. 2003) provides compelling evidence for the impacts of environmental change, and the recording program will continue into the future. Other areas of natural history have not been so well served.

Teaching in the field is still a component of many University courses but is under great pressure because of cost, occupational health and safety issues (which can create bureaucratic nightmares), the large number of students with part-time jobs who find it difficult to attend courses at weekends or during vacations, and because of the decline in the number of academic staff with knowledge of many groups of organisms. The long-term future of field teaching is very uncertain and this will have major consequences for our ability to produce graduates capable of addressing biodiversity issues.

Peter Marren (2002, 2005) has written on a number of occasions, pointing out the loss of expertise in UK institutions and the decline in the numbers of skilled amateurs. At the same time there is an increase in the membership of NGO conservation societies, indicating wide support for natural history, but the deep engagement with some particular field within natural history is less common. There may be many and varied reasons for this, but Marren suggests one may be that, with the modern pressures on many people, and the absence of time, natural history had become a spectator rather than participant sport. The quality and expertise shown in recent TV natural history programs is such that rather than encouraging participation they suggest that we already know everything. This is an idea that needs further exploration.

The achievements of Linneaus and his students were remarkable and the detail of their observations made with minimal technological aids, was particularly remarkable. Few students today would have the capacity or patience to make similar investigations. Experimental science needs to be underpinned by substantial bodies of observation in order that appropriate hypotheses can be generated and tested. Linnaeus' legacy of observation has been built upon for the last 250 years, but the capacity to continue to do so is being lost.

Contrary to the impression left by Conniff, we would argue that Linnaeus also laid the foundation for other major areas of ecology, including comparative biogeography (long before van Humbolt), plant demography, and comparative anatomy. His legacy was far more encompassing than taxonomic, even though the systematic recording of species remains absolutely fundamental to modern ecological concerns.

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(Endnotes)

[1] *He variously reported traveling up to three times further than he really did and spoke of long periods spent with the native Sami, when in fact it was a few weeks. The fact that he was being paid by the mile for his journey by the Science Society of Uppsala is cited by way of partial explanation (Koerner 1999).*